A COMPRESSED AIR DEVICE FOR ACOUSTIC AND GENERAL LABORATORY WORK.[1]

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A short time ago, I published a brief description of a simple form of compressed air apparatus which served a useful purpose in experiments with the Appunn tonometer and the Stern blown bottle.[2] At the suggestion of Dr. Stern, I have since elaborated this air-compressor until it is now in a form which renders it useful for many kinds of acoustic work, such as the actuating of bottles, organ-pipes, reed-boxes, Quincke tubes, the Galton whistle and like instruments. It is equally serviceable for any other laboratory purposes which require a perfectly uniform blast of air at moderate pressures and without the presence of hisses or other disturbing noises. The new form will also satisfy a requirement which is not met in the bellows type of machine, for it allows entire freedom to the operator; aside from the brief time consumed in changing the counterweight every two or three minutes, a continuous blast of air at constant pressure is automatically provided.

The original cruder form of the air-compressor was built upon the principle of the gasometer. A galvanized iron cylinder, 30 cm. in diameter and 75 cm. long, was inverted and lowered into a second slightly larger cylinder filled with water. Suitable weights caused the upper cylinder to exert a pressure upon the air above the water, the upper sliding down within the lower cylinder as the air was used. The upper cylinder was then raised with a counterweight when exhausted.

While this simple form of apparatus will answer sufficiently well for many purposes, it has certain defects which become serious when it is desired to work more rapidly and with greater exactness. In the first place, the supply of air is exhausted in from 15 to 30 seconds. Secondly, it can be renewed only by allowing the rising cylinder to draw in a fresh volume of air, a process which takes some three-quarters of a minute. And, finally, the displacement of water by the descending cylinder gradually decreases its effective weight and therewith the air pressure.

In the improved form of apparatus, the first defect has been

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[1] From the Laboratory of the Department of Education, Cornell University.

[2] This *Journal*, XII, 1902, 221.

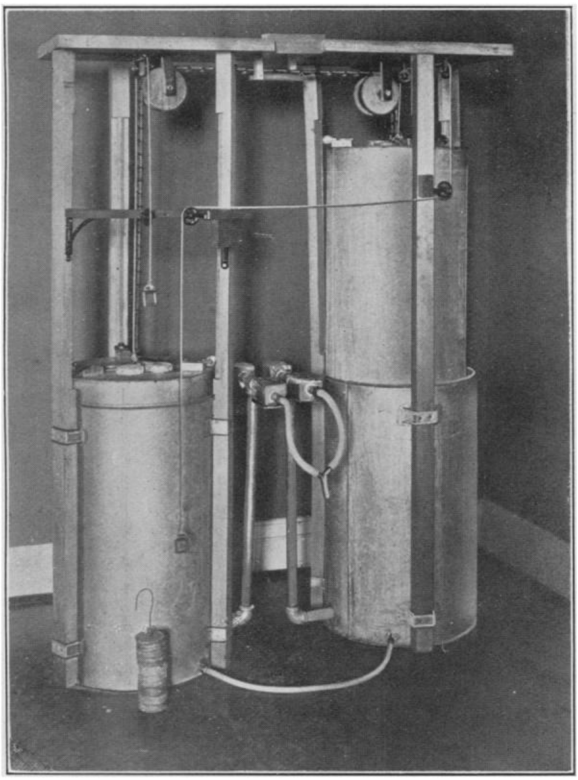
overcome by increasing the size of the tanks. The second defect has been overcome by employing two tank systems, which are exact duplicates of each other, and so arranged that the one tank is filling while the other is emptying. The third defect has been removed by a compensating device, which serves at the same time to join the two moving cylinders.

The general appearance and mode of construction will be understood from the accompanying cut, which represents the somewhat rough 'home-made' product of our experimentation. It will be seen that in each tank system there is a water tank 82 cm. high and 48 cm. in diameter. This tank is in reality double walled, as there is an inner cylinder 43 cm. in diameter, invisible in the cut. These cylinders have, of course, a common bottom, so that the space between them is water-tight. This dispenses with a great deal of weight which would otherwise result if the entire tank were filled with water. The outer wall is pierced near the bottom to admit a half-inch pet-cock, which facilitates the draining of the water when necessary, and which also serves to connect the water spaces of the two tank systems, as is desirable under some conditions. Both the outer and the inner walls are also pierced, as near the bottom as possible, to admit a 1-inch galvanized iron pipe for the air transmission. Six lugs or handles for the attachment of vertical supports (iron rods or wooden posts, 181 cm. long [1]), are riveted and soldered to the outer cylinder, three near the top, three near the bottom. A solid wooden plank caps the posts and forms a support for raising the tanks.

The upper or moving tanks are 79.5 cm. long and 45.5 cm. in diameter, so that, when inverted, they slide easily into the water space of the lower tanks. On the center of the flat top a heavy ring or iron loop is fastened to serve as the attachment of the connecting chain and counterweight cord, and at three points on the edge are fastened the pulleys (3.5 cm. in diameter) which serve to guide the cylinders by travelling along suitable ways on the vertical supports.

The two tank systems thus constructed are now placed side by side with the air pipes facing each other. The wooden top-boards are joined by two small braces. The moving tanks are connected by an iron chain (180 cm. long and *circa* 2.6 kg. in weight) such as is sold for agricultural machinery as "Number 052 link belting." This passes over two large wooden pulleys (13 cm., outside diameter) which are firmly fastened to the wooden top-board of each tank system. A simple support must also be placed midway between the pulleys:

[1] In the apparatus pictured, wooden joists, 5.5 x 4.5 cm. cross section, were used. Iron pipes would be quite as efficient and much lighter in appearance, as only two uprights would then be required for each tank.



otherwise vibration of the chain will produce a 'puffing' effect upon the air blast. This chain is employed instead of a more flexible material, such as rope or leather belting because it possesses just the required weight. Evidently, in using the duplicate tank form of compressor, the error of displacement is doubled, for when one tank descends and thus loses weight by immersion, the other tank rises at an equal rate and thus gains in weight. Since the rising tank, from the manner of construction, is dragging on the descending tank, its variable weight-error is added to that of the descending tank. The chain used weighs per cm. exactly twice the amount lost per cm. by one tank as a result of displacement; in operation it therefore exactly counteracts the displacement-error.[1]

Pressure is exerted upon the air system by means of a counterweight (*circa* 9 kg.) which nearly removes the pull of one tank upon the connecting chain, thus allowing the other to drop by its own weight. For some purposes the weight of the air tank itself furnishes sufficient pressure, but in many cases it is necessary to increase this pressure. This is most easily done, as shown in the illustration, by placing flat lead weights upon the top of the tank. It is obvious that weights of equal value must be placed upon both tanks and also upon the counterweight.

To facilitate the rapid handling of the apparatus a single counterweight only is employed. By means of small pulleys a cord is brought from the top of each air tank to a point in front of one of the tanks and about 136 cm. from the floor. After passing over the last pulley each cord terminates in an iron ring; this serves by its weight to keep the cord sufficiently taut and furnishes an easy means for attaching and detaching the counterweight. The latter is made preferably of lead with removable discs to vary its weight. It is clear that, when one tank is emptied, the other can be at once set in motion by simply lifting the counterweight from the lower to the upper cord-ring, an operation which consumes less than five seconds. *This brief task of occasionally raising the counterweight is thus the only attention which the air-compressor demands:* the operator is otherwise entirely free to conduct his experiments.

The air system, as has been mentioned, is made up in part of a short (11 cm.) iron pipe projecting from the bottom of each water tank. This piece is continued upward by an elbow and straight piece (76 cm. long) which terminates in a T-piece with a short pipe projecting from each arm. Upon these arms are screwed the check-valves, two for each tank system (one

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[1] This might be effected, perhaps, by the use of a flat, flexible belt of thin leather or woven linen, to which small lead weights should be fastened at frequent intervals. The pulleys could then be made much smaller.

opening inward and the other, which leads to the instruments, outward). It will be seen that these valves are essential to the rapid manipulation of the machine, for otherwise it would be necessary to turn four valves whenever either tank was exhausted. As it was impossible to purchase air-tight valves of sufficient delicacy, these were constructed in the laboratory. Though they are somewhat bungling in appearance they are easily and cheaply made and work to perfection. Each valve is built in a wooden box 7.5 x 7.5 x 11 cm. The joints are made tight with melted paraffine, though the top is preferably screwed down against a layer of chamois or thin rubber smeared with white lead, so as to be more easily removable for inspection or repair. The ends of the valve boxes consist of wooden blocks bored to receive the iron pipes. In each box one of these pieces is planed off on its inner surface at an angle of about 15 degrees (the longer face being on the bottom). A piece of brass tubing (30 cm. in diameter) is then driven into the block and brought to an even edge slightly projecting from the oblique surface. This forms the seat of the valve. The flap is made of a sheet of thin flexible rubber (such as is sold in strips for bandages) to which is cemented a piece of 1-16th-inch hard rubber slightly larger than the seat of the valve. The soft thin rubber, being next the brass tubing, forms an air-tight valve of the 'flap' or 'butterfly' type (the upper end serving at the same time as the hinge), while the hard rubber provides a perfectly flat, rigid surface at the line of contact. The outward opening valve-boxes have attached to them a half-inch pipe leading to the instrument to be blown.

The amount of air available in the tanks just described (over 128 liters before compression) is sufficient to actuate a small organ pipe (*e. g.* of 220 vibs.) continuously for two minutes 45 seconds and the Stern blown bottles nearly as long, *i. e.*, about eight times as long as the smaller machine first constructed. In case a large quantity of air at a relatively high pressure is desired for shorter periods, this may be readily secured by raising both tanks and allowing them to fall simultaneously.

In comparison with the large Appunn bellows,—the laboratory instrument most commonly used for like purposes,—the compressed air device which I have described will be found to present many advantages. It occupies no more floor space; it delivers air with absolute uniformity and at far less expenditure of time and energy on the part of the operator. Finally, its first cost is much less [1] and it is distinctly less liable to deteriorate with use and age.

[1] The writer will gladly submit estimates for the construction, in Ithaca, of duplicates of this apparatus.